



NMSD - REQUIREMENTS REVIEW AGENDA

Introductions

Proposal Overview

Leverageable Technologies At COI

Basic Phase Programmatic

Basic Phase Requirements

Technical Approach

Action Items



NMSD - REQUIREMENTS REVIEW

PROPOSAL OVERVIEW



NMSD - PROGRAM

Program Objective:

- **Demonstrate That a /10 or Better; <15kg/m² Primary Mirror Can Be Made at an “Acceptable” Cost/Schedule**
 - Target Flight Unit Cost <\$100M for Telescope Assy
 - Year 2006-2007 Launch

Program Phases

- **Basic Phase-**
 - NGST Mirror System Demonstrator (NMSD) Preliminary Design/Analysis
 - NMSD Test Plan
 - PDR (2 October 1997)
- **Option 1 Phase- To Be Awarded at Completion of Basic Phase**
 - NMSD Final Design/Analysis
 - NMSD Fabrication, and Requirements Conformance Testing
 - Final Review
- **Option 2 Phase- To Be Awarded at Completion of Option 1**
 - NMSD Thermal/Vac/Optical Testing; Non-Destructive Dynamics Testing
 - Test Reviews



NMSD - DEVELOPMENT TEAM

COI

- Engineering
- Composites Fabrication
- Sub, and Final Assembly

Eastman Kodak

- Engineering Support: Mirror Structure; Systems; Metrology
- Mirror Surface Processing
- Mirror Final Inspection and NMSD Demonstration

Waterjet Technologies, Inc.

- Blank Facesheet Lightweighting

WJ Schafer Associates, Inc.

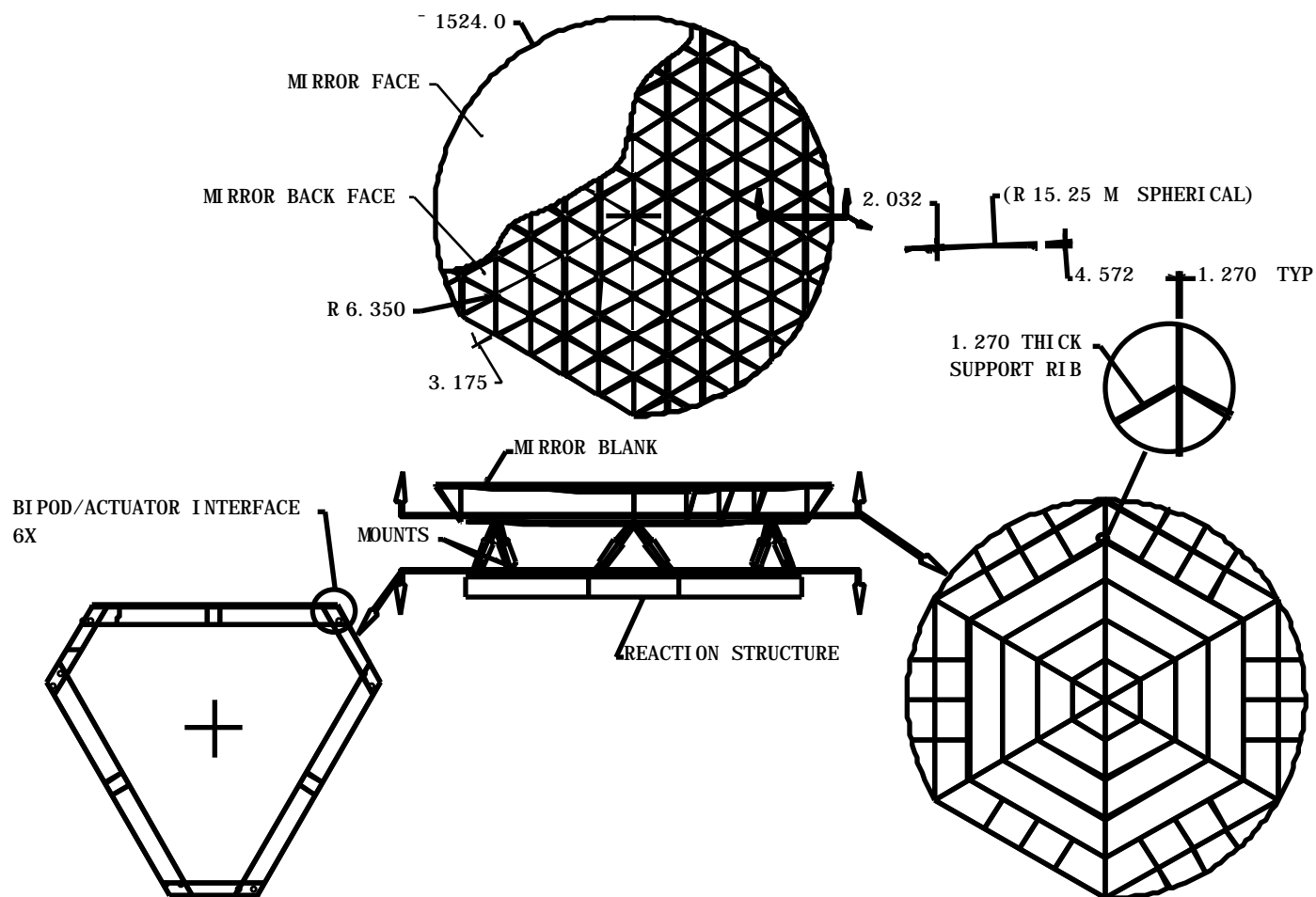
- Systems Engineering Support
- Actuator/Flexure Engineering Support

University of Arizona

- Cryogenic Materials Testing

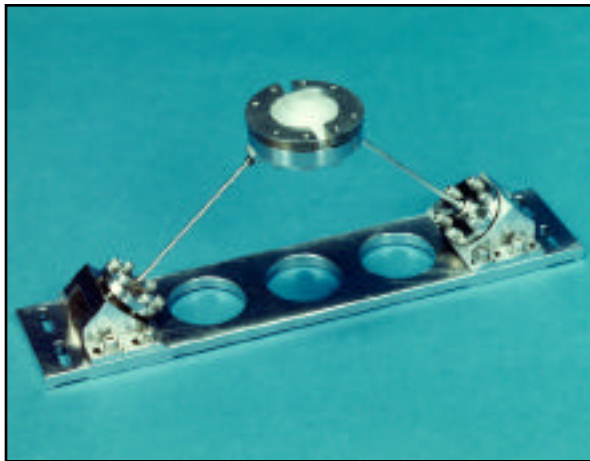


NMSD - PROPOSED GEOMETRY





KODAK IR&D MIRROR ASSEMBLY

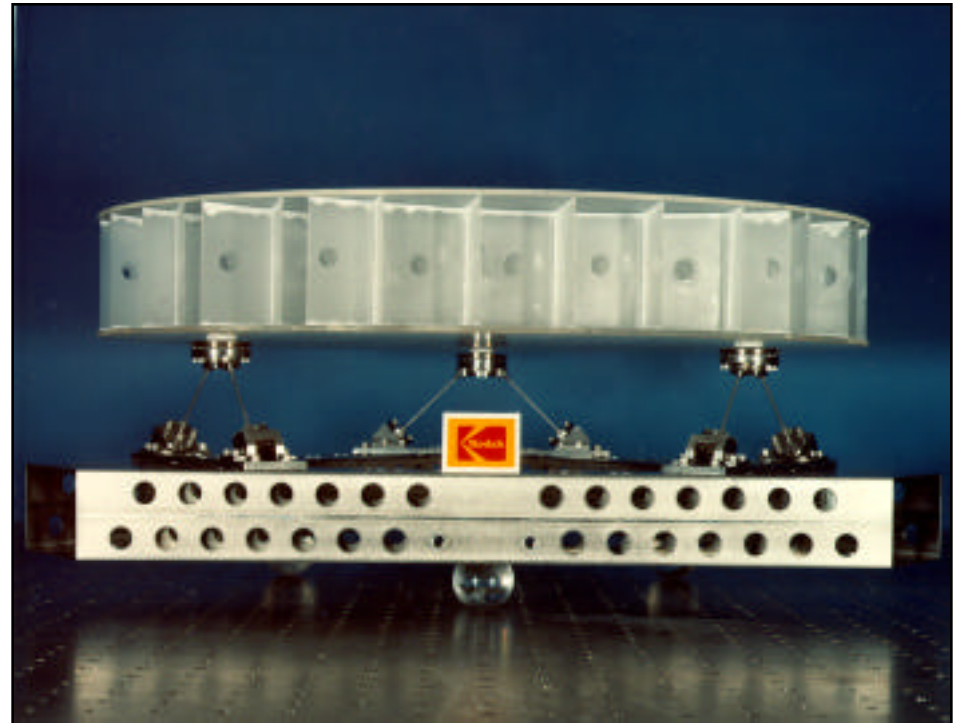


ULE™ Frit Bonded Mirror

**Invar Reaction Structure and
Flexure Mounts**

Design to Operate at $< 10^{\circ}\text{K}$

Tested Successfully to 90°K





NMSD - PROPOSED FAB / ASSEMBLY APPROACH

Mirror (Substrate) Subassembly

- 40mm Thick Blank Zerodur Ground to 15.25m RoC, 7mm Thick (Kodak)
- Shaped Glass to Be Light-Weighted (Waterjet Milled) to Form Isogrid Stiffened Mirror Substrate (Waterjet Technologies Inc.)
- Composite Core Structure Bonding to Shaped Glass w/TBD Adhesive (COI)
- Preliminary Figuring of Mirror Subassembly to <0.10 RMS (Kodak)
 - Analytically Derived Figure Compensation for 35°K/0g Operation

Reaction Structure Subassembly (COI)

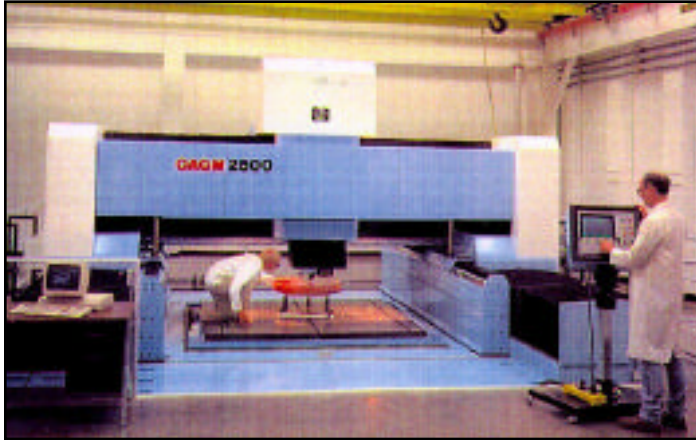
- Bonded Composite Tubes Primary Structure
- Bonded Invar Mounts for Actuator Attachment and Mirror Assy Testing

NMSD Final Assembly (CO I/ Kodak)

- Mirror Substrate Actuators / Flexures Integration Onto Backplane
- Mirror Substrate Integration Onto Actuators/Flexures
- Interferometer Inspection of Figure
 - Analytically Derived Figure Compensation for 35°K; Simulated 0g @ Inspection



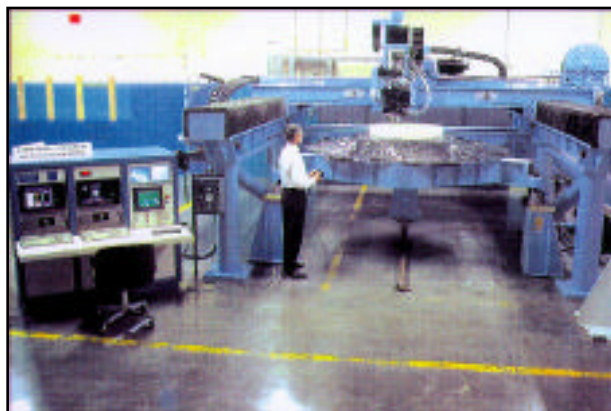
KODAK MIRROR OPTICAL FINISHING



Primary Mirror Surface Generation



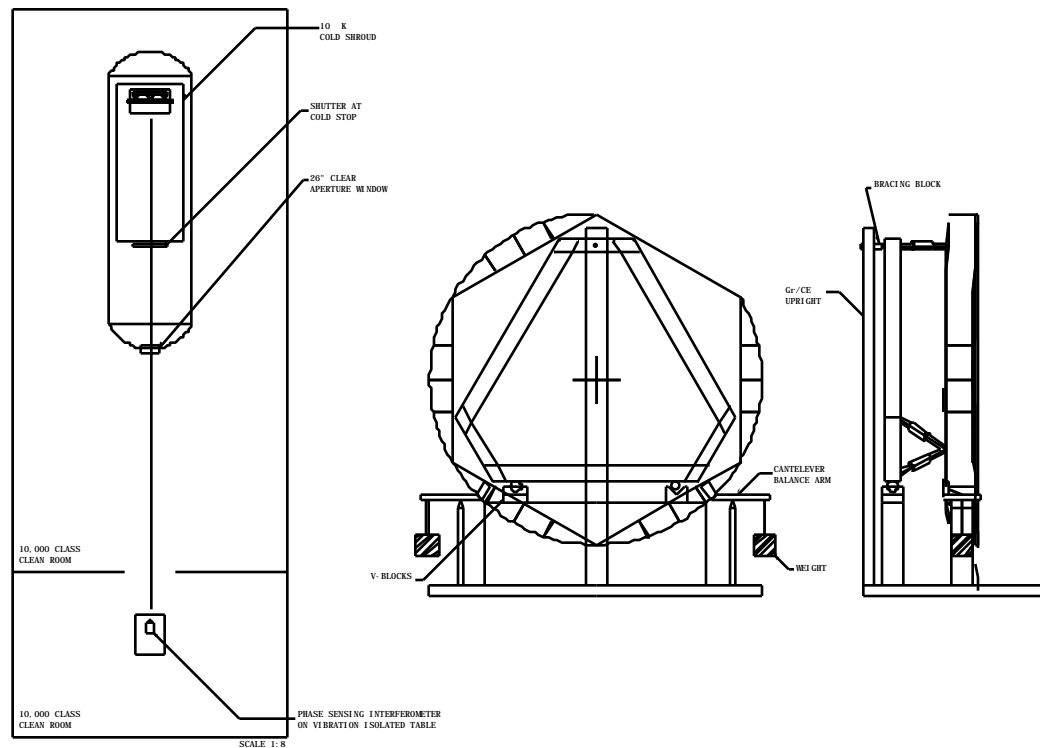
Final Figuring



Preliminary Figuring



OPTION 2 NMSD OPTICAL DEMONSTRATION SIMULATED SPACE ENVIRONMENT



**Test to be Conducted at
AEDC (Chamber 10V)**

- **1g Compensation System**

Optical Demonstration at

- **Ambient**
- **~77°K/Vacuum**
- **~35°K/Vacuum**



NMSD - PRELIMINARY TEST PLAN

Start Point, Option 1 Measured Figure

- | | |
|----------------------------------------------------|-------------|
| – Initial Optical Test In Thermal/Vac Chamber | Test Step 1 |
| • Without Chamber Window, Ambient Conditions | |
| – Optical Test at Ambient (~290°K;1 atm) w/Window | Test Step 2 |
| – Optical Test at ~290°K; Vacuum (10^{-8} Torr) | Test Step 3 |
| – Optical Test at ~77°K/ 10^{-8} Torr | Test Step 4 |
| – Optical Test at ~35°K/ 10^{-8} Torr | Test Step 5 |
| – Optical Test at ~77°K/ 10^{-8} Torr | Test Step 6 |
| – Optical Test at ~290°K/ 10^{-8} Torr | Test Step 7 |
| – Optical Test at Ambient Conditions | Test Step 8 |

Data Evaluation to Determine Final Figuring Parameters (Kodak/COI)

Vibration Testing (Modal Tap) of NMSD

Final Figuring to $< \lambda/4$

Final Thermal/Vac

- Test Step 2 through 8 @ AEDC



NMSD - REQUIREMENTS REVIEW

***LEVERAGEABLE TECHNOLOGIES AT
COI***



COI LEVERAGEABLE TECHNOLOGIES

Previous Contracts

- **Ultralightweight Mirrors**
 - Kodak ULE Hybrid Mirror
 - DARPA Mirror
 - HALO Mirror

Concurrent SBIR and IRAD Activities

- **Mirror Technologies**
 - Phillips Lab Ultra-Lightweight Hybrid (2.5m RoC Spherical)
- **Moisture Barrier Technologies**
 - MSFC Phase I Materials/Processes
- **Tooling Technologies**
 - MSFC Phase I Low-Cost Replication Tooling
 - Castable Ceramic, Low-CTE Blocking Bodies



COI TECHNOLOGY PROGRAMS

<i>Primary Development Programs</i>	MSFC Tooling Ph I SBIR	Replication IRAD MSFC X-Ray Mirror Ph II SBIR (Pending) JPL Mirror Ph II SBIR ISUS Concentrator	Phillips Lab Mirror Ph I SBIR MSFC Mirror Ph I SBIR Kodak ULE Hybrid IRAD AeroMet Hybrid	MSFC SBIR Barrier Ph I SBIR
<i>Mirror Technologies>>></i>	Low-Cost Tooling Castable Refractory Formed Glass Surfaces Thick Ni Alloy Plating	Specular Surfaces Accurate/Low-Cost Replication Alternate Surfacing Processes/Materials Insitu Mold Release Ni Alloy Plating Supersmooth Surface	Lightweight Structure Advanced Core Hybrid Composites	Moisture Control Surface Barrier Processes/Materials
<i>Beneficiary Programs</i>	Phillips Lab Mirror Ph I SBIR JPL Mirror Ph II SBIR	Phillips Lab Mirror Ph I SBIR MSFC Tooling Ph I SBIR MSFC SBIR Barrier Ph I SBIR	JPL Mirror Ph II SBIR	Phillips Lab Mirror Ph I SBIR JPL Mirror Ph II SBIR



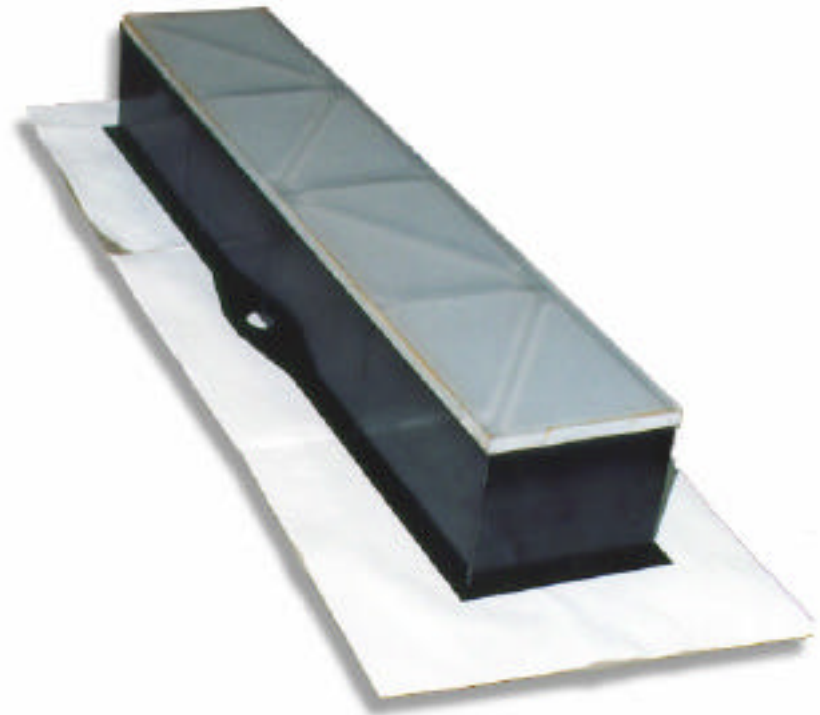
KODAK / COI HYBRID MIRROR



**ULE™ / Composite
Lightweighted Facesheet**

12 kg/m²

**Room Temperature
Application**





PHILLIPS LAB PHASE 1 SBIR

Study Objective

- **Enabling Technology to Develop Production of Ultra-lightweight Meter Class Space Optics**

Study Goals

- **5 - 10 kg/m² Areal Weight**
- **Visible and Near Visible Range**
 - **Target Figure /40 RMS; Roughness 10-20 Angstroms**
- **Technology Target: >1.5 meter**
- **Compatible with Space Environment**

Phase I .25m Polymer Matrix Test Mirror Deliverable

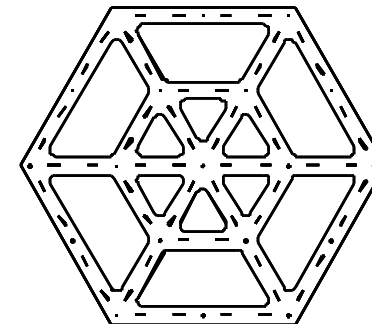
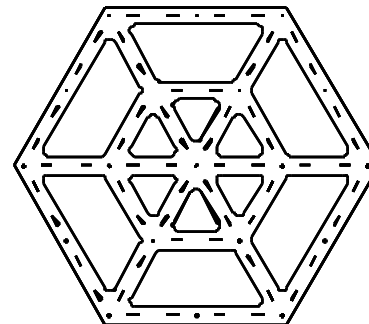
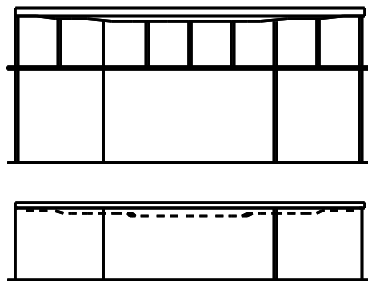
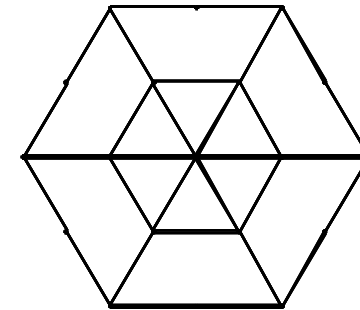
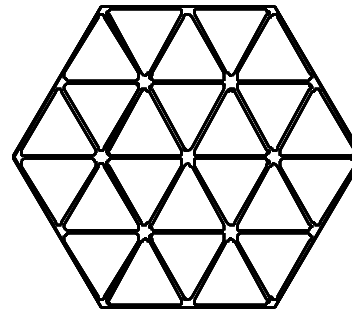
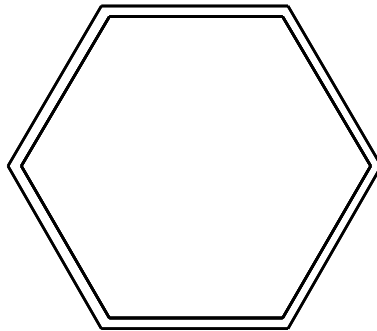
- **2.5m Radius of Curvature Surface**
- **Oct 1997 Delivery for Test**



PHILLIPS LAB PHASE 1 SBIR

Transferable Technologies: Lightweight, Hybrid Mirror


- Composite Substructure
- Flexure Mounted, with Option of Fixed Surface Glass Mirror
- Waterjet Pocket Milled Glass
- Bonded Structure





DARPA MIRROR

Ultra-lightweight Precision Mirror Development



/50 @ 0.633 μm

**Composite Substrate with
0.1" ULE Facesheet**

Flexured Mirror

**15 msi Substrate
Modulus of
Elasticity**

36" Aperture

**15.3 kg/m² Areal Density
(8.3 Substrate, 7.0 Glass)**

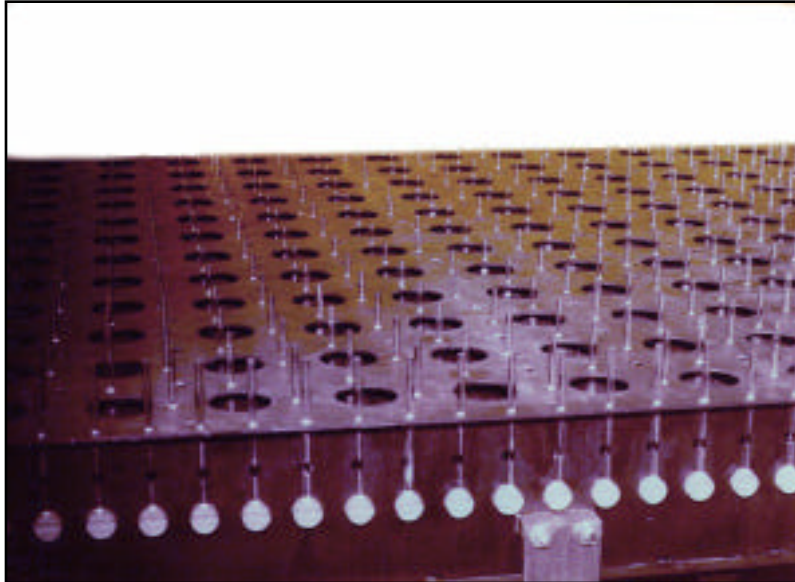
CTE = +/- 0.05 ppm/°F

**Proprietary
Moisture
Barrier Applied**

Figure Stability Over 2 Years Demonstrated



HIGH ALTITUDE LARGE OPTICS



**Fused Silica Dual Cylinder Flexures
(540) @ Substrate Midplane
Flexures Match Machined in Place to
Spherical Contour
Substrate CTE +/- 0.5 ppm/°F
15 msi Substrate Modulus of
Elasticity**

Active Design

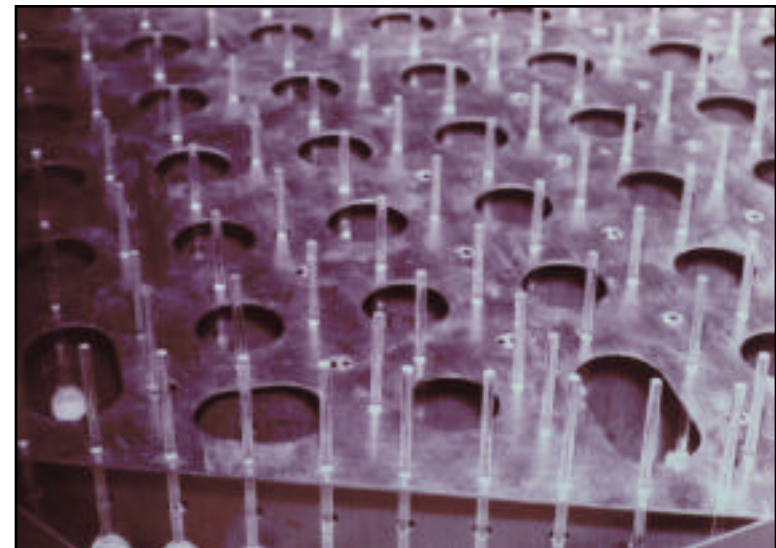
30" x 40" Aperture

**Composite Substrate With 0.15"
Fused Silica Facesheet**

/20 @ 0.633 μm

**Operating Temperature Range -
320°F/ +250°F**

**16.5 kg/m² Areal Density Without
Actuators (9.4 Substrate, 6.1 Fused
Silica)**





NMSD - REQUIREMENTS REVIEW

BASIC PHASE PROGRAMMATICS



BASE PHASE OUTLINE

Task 1: NMSD Preliminary Design and Analysis

- NMSD Concept and Detailed Design Development
- Analyses of Demonstration and Operational Requirements

Task 2: Option 1 and 2 Test Plan

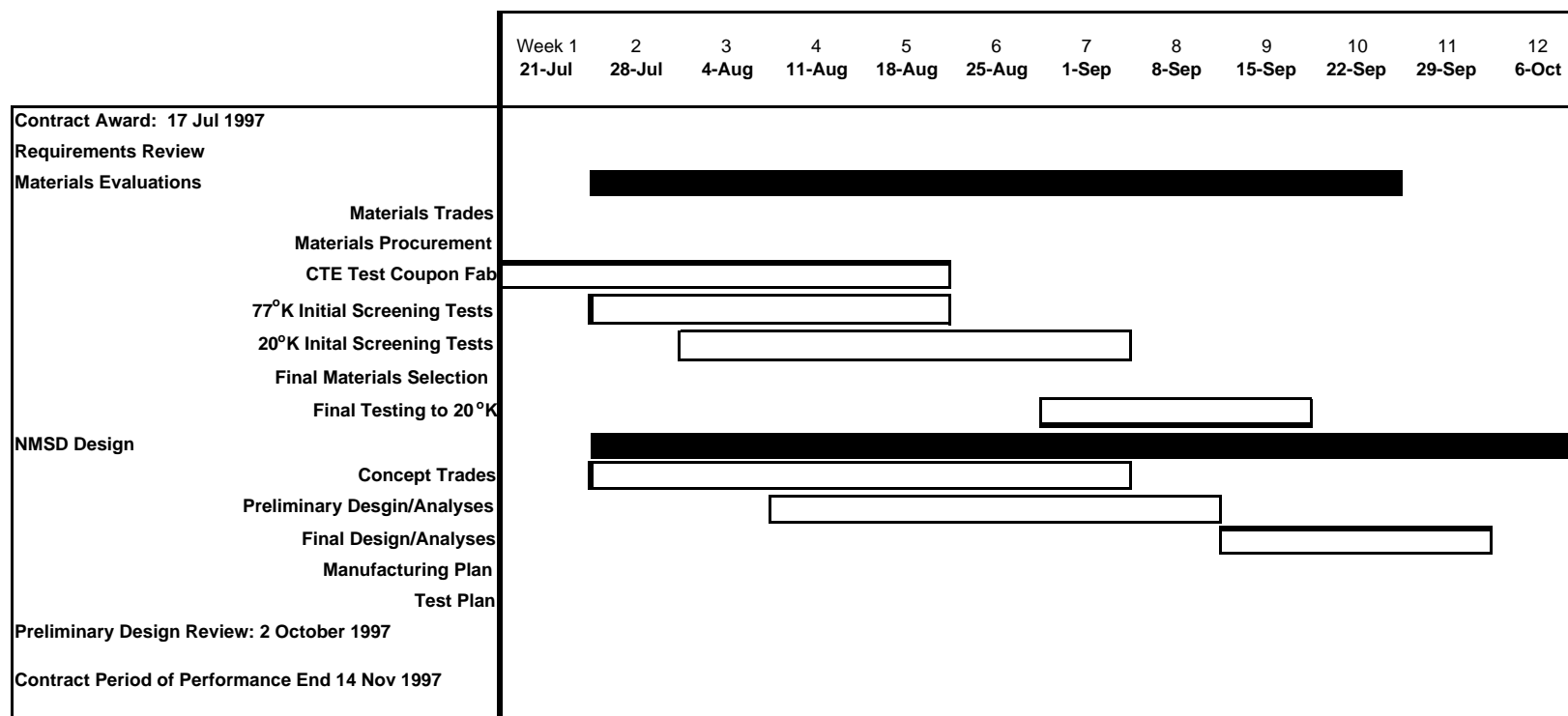
- Test Objectives
- Test Descriptions
- Facilities and Equipment
- Schedules

Task 3: Documentation and Delivery

- Requirements Review Presentation RR (31 July 1997)
- Preliminary Design Review Presentation PDR (2 October 1997)
- Supporting Analysis and Models PDR (2 October 1997)
- NMSD Test Plan PDR (2 October 1997)
- Progress Review Presentations NGST Quarterly Reviews

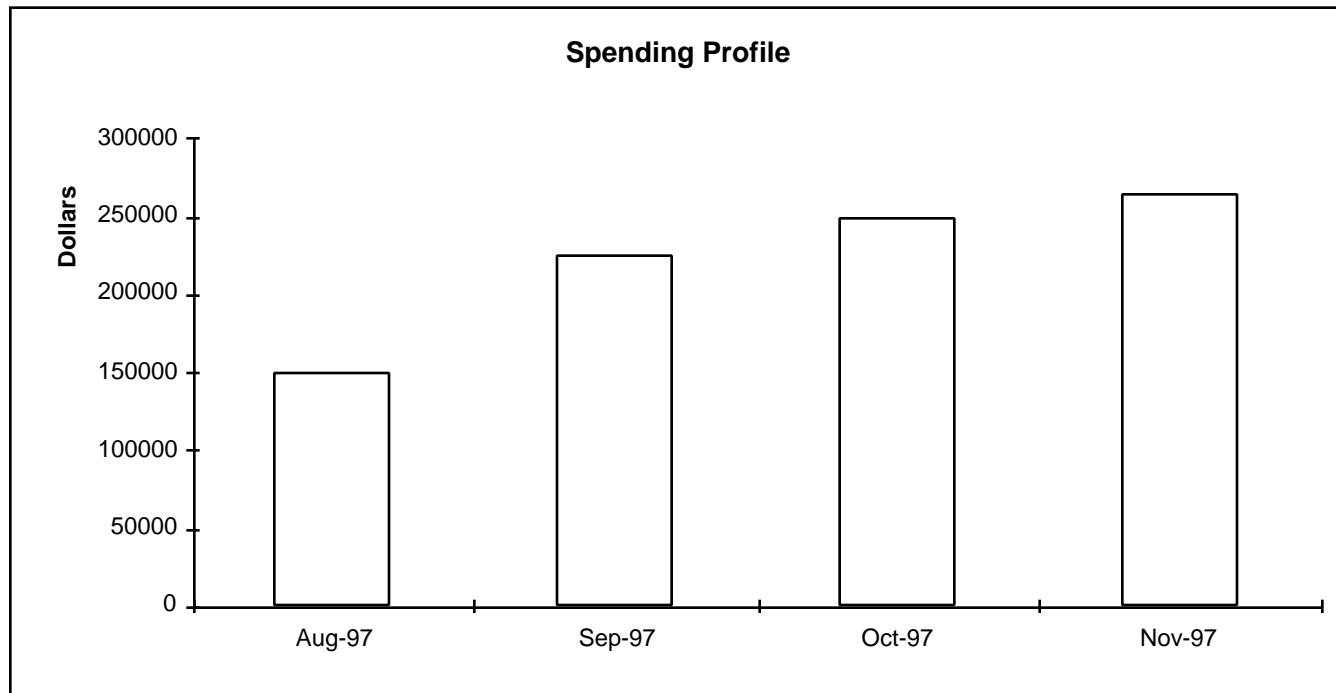


NMSD - BASIC PHASE SCHEDULE





NMSD - BASIC PHASE SPENDING





NMSD - REQUIREMENTS REVIEW

BASIC PHASE REQUIREMENTS



NMSD - MIRROR / ASSEMBLY REQUIREMENTS

<u>PARAMETER</u>	<u>VALUE</u>	<u>GOAL</u>
Footprint	Circular with one flat edge	
Flat Length	One Half the diameter	
Diameter	>1.5m	2.0m
Shape	Spherical	
F/No.	f/6	f/5
No. of Actuators	As required for figure and/or phasing capability	
Figure	< /4 (= .633 micron)	< /10
Mid-Spatial Errors	< /10 (= .633 micron)	< /20
Mid-Spatial Scale	1 - 10 cm	
Finish	<2.0nm RMS	1.0nm RMS
Areal Density (mirror/backplane)	15kg/m ²	<15kg/m ²
NMSD Optical Performance		
Simulated Space Environment	70°K Min. Temp	35°K
NMSD Dynamic Characteristics	TBD	



NMSD - REQUIREMENTS COMPLIANCE

Mirror Geometry (Footprint, Flat Length, Diameter, Shape, F/No.)

- Basic Phase Initial Design Definition
- Option 1 Inspection

Mirror Surface Performance (Figure, Mid-Spatial Errors, Finish)

- Option 1 Demonstration
 - Measured Figure @ Ambient
 - Analytically Derived Figure Compensation for 35°K
 - Analytically Derived Figure Correction for 0g
 - Simulated 0g @ Inspection
- Option 2 Demonstration
 - Test Derived Figure Compensation for 35°K
 - Measured Figure @ Ambient
 - Analytically Derived Figure Correction for 0g
 - Simulated 0g @ Inspection



NMSD - REQUIREMENTS COMPLIANCE

Areal Density

- Basic Phase Initial Design Definition
- Option 1 Inspection

NMSD Optical Performance in Simulated Space Environment

- Option 2 Demonstration
 - 77°K/10⁻⁸ Torr
 - 35°K/10⁻⁸ Torr

NMSD Dynamic Characteristics

- Option 2 Demonstration
 - Non-Destructive Modal Tap Test of NMSD at Frequencies up to 350Hz



NMSD - REQUIREMENTS REVIEW

TECHNICAL APPROACH



NMSD - BASE PHASE ENGINEERING ACTIVITIES

Concept Development/Refinement Studies

- Glass/Composite Hybrid
- Passive Figure Control: Engineered Materials Application
- Demonstrated Manufacturing Techniques

Preliminary and Final Analyses

- System Level Requirements Compliance
- Manufacturing, Inspection and Handling (i.e. Figuring Loads)
- Thermal/Vacuum and Dynamics Testing

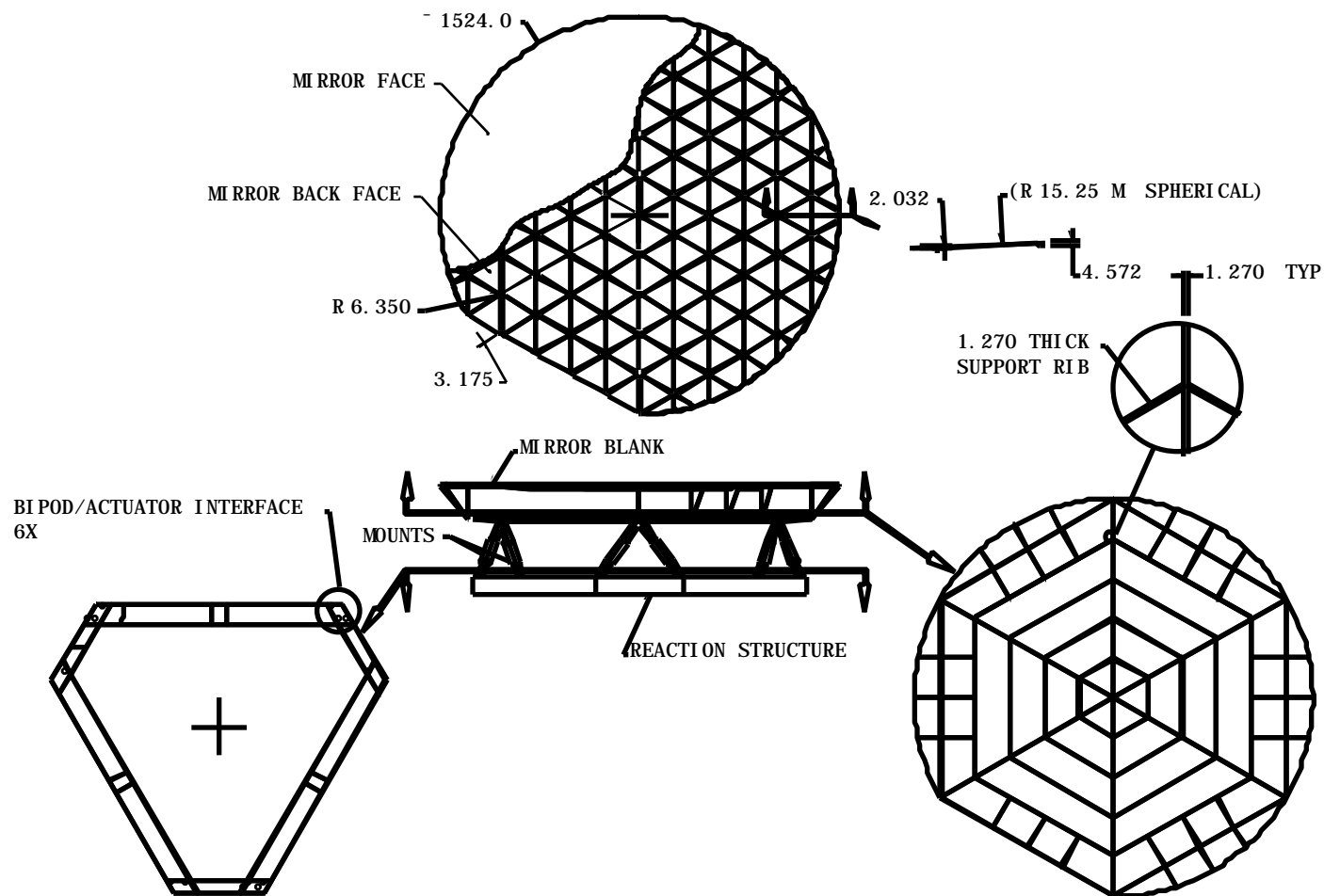
Engineering Design Documentation

Manufacturing Plan for Option 1 Activities

Test Plan for Option 1 and 2 Activities



NMSD - PROPOSED GEOMETRY



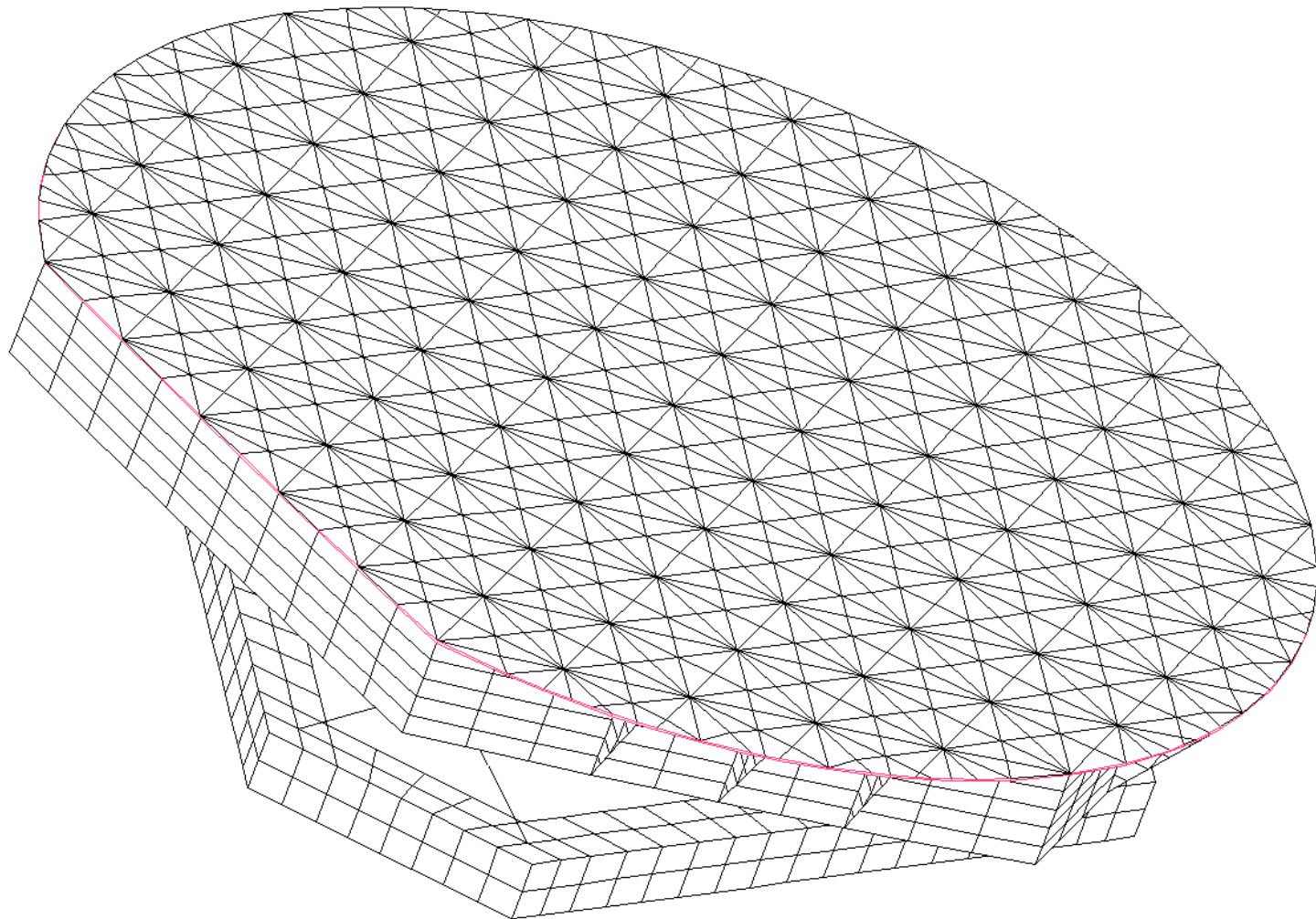


PRELIMINARY MASS PROPERTIES: 1.5M NMSD

Component	Mass (kg)	
Mirror Assembly		
Glass Face	8.3	
Composite Stiffening	5.2	
Flexure Mounts	3.2	
Composite Reaction Structure	2.4	
Mounting Fittings	0.7	
Contingency (10%)	2.0	
	21.8	Total Mass (kg)
	12.3	Areal Density (kg/m ²)



PRELIMINARY ANALYSIS MODEL





PRELIMINARY ANALYSIS RESULTS

Mirror Surface Material: Zerodur

- .07” Thick Membrane; .2 Wide x .1 Tall Isogrid Stiffeners

Mirror Substructure and Reaction Structure Material: M55J/954-3

- .04” Thick Backplate
- .02” Thick, 5” Tall Ribs, ~5” Spacing

Modal Analysis

- Flexures Modes: 157 Hz; 158Hz; 193Hz
- Mirror Surface First Mode: 244Hz (Perimeter Simply Supported)

Optical Demonstration- Effects of 1G Compensation on Figure

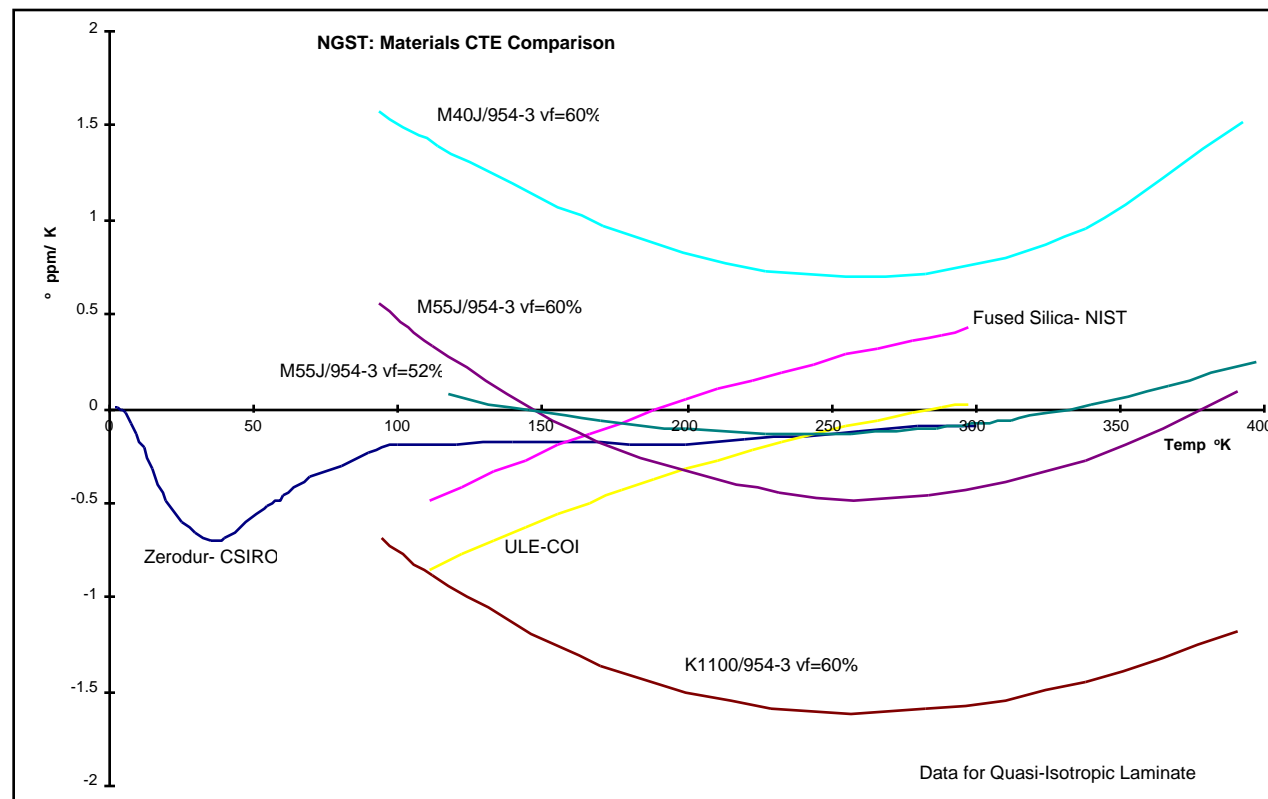
Support Condition	Figure	Peak to Valley
w/o 1g Compensation	.72 μ RMS	3.12 μ
w/ 1g Compensation	.06 μ RMS	.52 μ



MATERIALS

Base Phase Test Program

- Establish (CTE) Compatible Material System for Hybrid Mirror
- Preliminary Screening of Suitable Fiber/Resin Systems Based upon COI Experience Base (Database limited to 77°K)





PRELIMINARY MATERIALS TEST PLAN

Glass Materials Data Generation

- Zerodur Class 0/1 to 20°K
- Fused Silica to 20°K

Composite Materials Data Generation

- 77°K Preliminary Design Data
 - M46J; M55J/954-3 Etc
- 20°k Preliminary Design Data
 - TBD Fiber at Varying Fiber Volumes
- Final Characterization to 20°K
 - TBD Fiber, TBD Fiber Volume, 0°/90° Laminate Orientations

Adhesive Shear Strength at Cryo

- Data Available at 77°K and 20°K for EA-9394 (Composite Bonding)
- Minimal Data for EA-9309 @ Temperature (Glass to Composite)
- Alternate Adhesives Will Be Investigated



NMSD - REQUIREMENTS REVIEW

ACTION ITEMS